DOOSAN Document Transmittal Upper Trishuli-1 HEP (216MW)		Date 2022-05-26	DT No.: UT1-HEP-DHI-PC-D-0032	SHEET 1 OF 1
DOOSAN NEPAL BRANCH OFFICE	Address & Contact No. : Four Square Building, Naxal, Kathmandu, Nepal (P.O Box : 1387) + 977 1 692 3014	Project No. H20002	DOCUMENT DISPATCHED BY Courier Service ☐ Messenger ☐ Post-Air Freight ☐ Document System or E-mail ■ By hand ■	
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SUBJECT	Review Note RN-0130_Stability Calculations for the Surrounding Rock of Powerhouse Cavern (incl. Annex 1: Joint Survey Report)			

S. N.	REVIEW NOTE NO.	REVIEW STATUS	DWG. / DOC. NO.	REV.	DWG. TITLE / DOC. DESCRIPTION	REMARK
1	RN-0130	RR	UT1-C-300-CVL-DC-60001	0A	Stability Calculations for the Surrounding Rock of Powerhouse Cavern (incl. Annex 1: Joint Survey Report)	
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Received by :

Date :

Legend of Review Status
A : APPROVED
AN : APPROVED AS NOTED
RR : RETURN FOR RESUBMISSION
FI : FOR INFORMATION

DHI STAMP

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Doosan Heavy Industries & Construction Co., Ltd.

Discipline : Civil

UPPER TRISHULI-1 HEP (216MW)			
Client	**Nepal Water and Energy Development Company Private Limited**		
Owner's Engineer	**Tractebel Engineering GmbH / Jade Consult**		
REVIEW NOTE			
Contractor	**Doosan Enerbility**		
Title of the Document	Stability Calculations for the Surrounding Rock of Powerhouse Cavern (incl. Annex 1: Joint Survey Report)		
Document No.	UT1-C-300-CVL-DC-60001	Revision	0A
Date of Documents	23.05.2022	Received Date	24.05.2022
Transmittal Form No.	UT1-HEP-DHI-D-0231		
Previous Review Date/Status	N/A	Prev. Review Note No.	N/A
Review Note No.	**RN-0130**	**Present Review Date**	**26.05.2022**
		Present Review Status	**RR**
A: Approved AN: Approved as Noted RR: Returned for Resubmission FI: For Information, only			

General

The general concept of the design calculations appears to be acceptable. However, there are several items, which are unclear, and there are essential items which need to be properly addressed and evaluated in the report. This refers in particular to the expected monitoring histories of displacements and the development of stresses in the support elements.

These results are essential when monitoring the actual performance of rock mass during cavern excavation and comparing it to the results of the FE-model.

Stress Initialization and Boundary Conditions

Assuming that the cover thickness above the cavern roof is 300 m, the cavern height is 40 m, k = 1.3 and the unit weight of rock is 27 kN/m³, the generated in-situ stresses prior to excavation at mid cavern height shall be

σ_v = 320 m x 27 kN/m³ = 8.6 MPa

σ_H = 1.3 x 320 m x 27 kN/m³ = 11.2 MPa

Boundary conditions shall be selected that a k-value of 1.3 is determined prior to excavation for (1) the whole FE-mesh, and (2) *in the far-field, undisturbed stresses (= away from the cavern) during modelling of excavation*. This must be clearly demonstrated in the report.

Monitoring of Deformations at Extensometer Points in the FE-Model; Displacement Histories

To get necessary data of the extensometers for calibration of calculation results with actual monitoring data, the mesh needs to be regenerated. Straight lines shall be created where extensometers will be installed, and the mesh requires refinement along these lines. This allows to get displacement data from respective knots in the FE-grid. Mark the respective grid points in the FE-mesh, which represent the monitoring points along the extensometer. During the calculations one can read out respective x- and y-displacement data of the

marked knots as they are getting displaced during calculations. Respective displacement history plots shall be produced.

Monitoring of Deformations at Extensometer Heads in the FE-Model; Displacement Histories

Extensometer heads will be monitored with optical targets during excavation. As above, respective displacement history plots of extensometer heads shall be produced.

Monitoring of Stress Development in Rock Bolts and Dowels; Stress Histories

Stresses in support elements will be monitored during excavation with strain gauges and / or load cells. Respective stress history plots of selected support elements in the cavern roof and in individual bench sidewalls shall be produced.

Calculation sequence after mesh generation and stress initialization must be clearly followed and demonstrated with figures, namely:

1. Excavate (remove elements) for **Central Crown Section**
2. Apply re-action forces (50% of in-situ stress)
3. Calculate to equilibrium
4. Install shotcrete and rock bolts and prestress rock bolts (50% of work load)
5. Remove reaction forces
6. Calculate to equilibrium

7. Excavate (remove elements) for **Right (= Northern) Side Drift**
8. Apply re-action forces (50% of in-situ stress) in Right Side Drift
9. Calculate to equilibrium
10. Install shotcrete and rock bolts and prestress rock bolts (50% of work load), install dowels
11. Remove reaction forces
12. Calculate to equilibrium

13. Excavate (remove elements) for **Left (= Southern) Side Drift**
14. Apply re-action forces (50% of in-situ stress) in the Left Side Drift
15. Calculate to equilibrium
16. Install shotcrete and rock bolts and prestress rock bolts (50% of work load), install dowels
17. Remove reaction forces
18. Calculate to equilibrium

19. Excavate (remove elements) for **Bench I**
20. Apply re-action forces (50% of in-situ stress) in the Bench I
21. Calculate to equilibrium
22. Install shotcrete and rock bolts and prestress rock bolts (50% of work load), install dowels
23. Remove reaction forces
24. Calculate to equilibrium

25. Excavate (remove elements) for **Bench II**
26. Apply re-action forces …, etc. etc., until full excavation.

Wedge Analyses

Derivation of mechanical parameter in Tab. 7.3 is unclear. Where do the strength data come from? Reference? Why is strength of foliation higher than of cemented joints? Explain/clarify).

Why is Joint Roughness Coefficient JRC used? It is unclear which failure criteria for the discontinuities has been used in the calculations (Mohr-Coulomb or Barton?). Clarify.

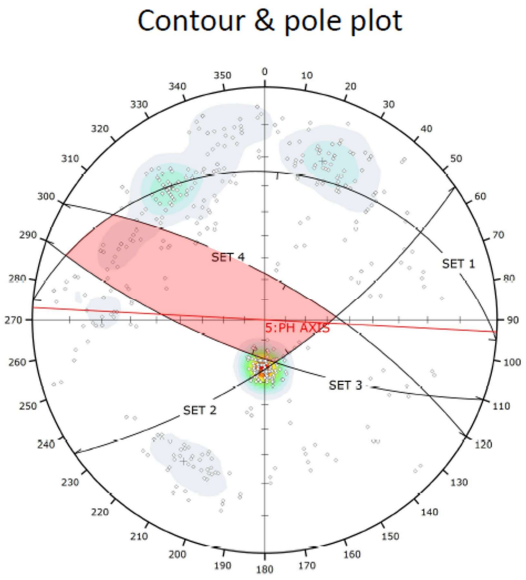
Wedge Analyses (tetrahedral wedges)

Despite there is sufficient and reliable geological data available (Annex 1; considered as an excellent geological data collection and presentation), the conducted wedge analyses are insufficient, and results may be misleading. It appears that wedge size has not been limited by the maximum extent of the plastic zone and/or maximum persistence of discontinuities. This can lead to the development of unrealistic large wedges.

Wedge size shall be limited by either apex-height (= max. extent of plastic zone), or persistence of respective discontinuities, whatever produces smaller wedges. The applied procedure shall be properly documented.

Wedge Analyses (prismatic wedges)

As shown in the hemispherical plot below, prismatic wedges (red-shaded in plot) are developing in the cavern roof. They are formed by the Joint Sets 1,2,3 and 4, and detaching from cavern roof through the foliation jointing, which must be assumed to have nil tensile strength.



The size of these wedges needs to be reliably determined / estimated from available geological data and respective **analytical** stability / support calculations shall be performed.

The document is returned for resubmission.

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Dr. Ulrich Glawe